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XVI. ZÖLLNER'S ANORTHOSCOPIC ILLUSION.¹

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In 1862 Zöllner described a modification of the anorthoscope consisting merely of a sheet of stiff black paper in which had been cut a slit of about two by forty millimetres, and a strip of white cardboard upon which any simple geometrical figure had been drawn.² By passing the white strip rapidly to and fro behind the slit the figure (a circle for example) is compressed laterally. Very slow rates give a corresponding lengthening of the figure. This illusion he distinguishes from those of the anorthoscope proper—where the distorted figure is merely a summation of a series of partial views of the true figure.

Helmholtz, in correspondence with Zöllner, and later in his *Physiological Optics*,³ suggested a physiological explanation for the lateral compression with fast rates, and a psychological one for the extension with slow rates. In his opinion the first is due to a movement of the eyes in the same direction as the figure, which would bring the experiment under practically the same principle as the ordinary anorthoscopic illusion, and the second depends upon the well known principle of the overestimation of small angles. Zöllner prefers a different psychological explanation in the second case, and points out that a psychological explanation is also probable for the illusion in the first case if it can be established that eye-movements are not concerned. To demonstrate this he placed a small mark half way up the slit, and made the experiment while the eyes were held steadily on this point. The result was the same as with free eyes. The illusion in the first form is obtained also, he says, with rates so slow that the question of after-images cannot be involved. He is, therefore, inclined to believe that the double illusion is due to an underestimation of fast rates, and a corresponding overestimation of those that are slow.

The illusion and the rival methods of explanation are interesting enough to invite a reinvestigation. A first step is, of course, to simplify the conditions and, in particular, to substitute a uniform movement in one direction for the variable to and fro movement of the hand apparatus. This was accomplished by drawing the figures upon a continuous band of paper

¹The experiments here described were made in the fall of 1896 and spring of 1897.

²Zöllner: *Ueber eine neue Art anorthoskopischer Zerrbilder*, *Poggendorff's Annalen*, CXVII, 1862, pp. 477-484.

³Helmholtz: *Physiologische Optik*, 2 te Aufl., p. 749.

carried on cylinders driven at a fairly constant rate.¹ The illusion was found to persist in unmistakable force and with fixed as well as free eyes. Indeed, the usual posture of observation taken by the subjects of their own accord consisted in fixation of the edge of the slit where the figure disappeared. Zöllner's explanation seems quite safe from attack on this ground.

A natural second step, and one suggested by Zöllner himself, is a quantitative study of the illusion. This is particularly interesting here, because the reversal of the illusion with the change from fast to slow rates promises an intermediate rate at which there should be no illusion—a rate, if Zöllner's explanation of the illusion is correct, which would be estimated without error. In order to avoid certain special factors of illusion which attend the use of a circular figure, a solid black square, 47 mm. on a side, and moving in the direction of one of its sides, was employed. Determinations were made for three widths of slit, 5 mm., 20 mm. and 47 mm. and for three rates of motion, 2.2, 4.9 and 25 cm. per sec. Thirteen subjects gave estimates of these nine cases, estimating each a single time, and nine of the subjects repeated the estimate a second time. The estimates were indicated by the subject on a suitably shaped strip of cardboard—not given in figures.² The first half of the following table gives the averages of the first estimates of the thirteen subjects; the second half the average of the second estimates of the nine subjects that made them.

RATE.	25 CM.	M. V.	4.9 CM.	M. V.	2.2 CM.	M. V.
APERTURE.	20.7	8.0	59.3	12.2	70.9	13.3
	29.5	4.4	54	6.3	60.5	8.5
	42.4	2.8	47	1.5	47.6	1.4
APERTURE.	24.7	7.2	58.5	11.9	68.6	13.2
	34.0	3.8	55.4	4.8	65.3	9.9
	44.1 ¹	1.6	51.0	4.3	50.0	4.0

¹ Estimates of 8 subjects.

Though the figures are rough as might be expected from the

¹ The driving power used consisted of the clock-work and weights of the large Krille Chronograph (pictured and described in Wundt's *Physiologische Psychologie*, 4 te Aufl., II, 338 ff.). This, unfortunately, does not, at least in the example in the Clark laboratory, give a wholly uniform rate of movement. The variation was not sufficient, however, to affect the general results of the experiment.

² [A possible exception to this is when the subject reported the figure as "square" without using the card. E. C. S.]

combination of the estimates of different observers, the general results are perfectly clear. The extent of the illusion diminishes as the width of the slit increases, and is almost wanting for a width of slit equal to that of the square (47 mm.). It is also probable, though it would need a more varied series of rates to prove it absolutely, that the illusory effect increases as the rate of movement changes in either direction from an indefinite medium rate. This medium rate, at which the illusion should vanish, appears to depend somewhat upon the width of the slit, but is something over 4.9 cms. per sec. for slits 5 and 20 mm. wide.¹ It is interesting to notice also that the mean variation of the estimates increases as the slit is made narrower, showing that the subjects vary more among themselves as the illusion becomes more marked. These relations accord with Zöllner's explanation: As the slit is narrowed the opportunity for estimating the rate becomes less and the possibility of illusion is increased; as the rate varies from a certain medium rate it is more apt to be misjudged; as judgment becomes more difficult individual variations are more apt to occur.²

It may be asked, however, whether there is any other evidence than that furnished by this illusion that rapid rates of movement are underestimated and slow rates overestimated. In reply it may be said that there seems some reason to believe that there is a general tendency to assign to ill-sensed quantities a medium rather than an extreme value, but this has not yet received the study that its importance as a psychological principle deserves.³ But irrespective of this general principle it seems to be a fact that such tendencies are active in our judgments of rate of movement, as is strikingly shown by an analogous experiment in the field of passive touch, where erroneous judgment seems to be the only possible explanation. The experiment is given by Loeb in his paper on the Tactual Space of the Hand, and is in the last degree simple.⁴ A string is drawn, at different rates of speed, between the thumb and index finger of a subject who presses it lightly and judges its

¹ All of the rates used were much less than the rate found by Lamsky for the rate of the eye's own movement—(*Pflüger's Archiv*, II, 1869, 418-422); so that the rate most correctly judged is probably not a function of the eye's own rate; unless, indeed, the eye's rate is materially slower for short movements than for long.

² By judgment, i.e. here meant, of course, not full and conscious logical inference, but the same sort of perceptive inference that is used in seeing form by means of the distribution of light and shade, or distance by the size of known objects.

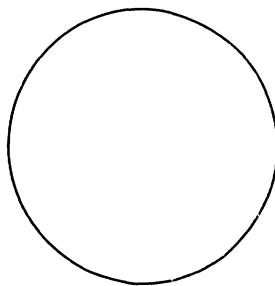
³ Leuba some years ago noticed something similar in sense memory. *Amer. Jour. Psy.*, V, 1892-93, 382 ff.

⁴ Loeb: *Untersuchungen über den Fühlraum der Hand*. *Pflüger's Archiv*, XLI, 1887, 107-127.

length without the use of his eyes. If the string is drawn slowly it is overestimated, if rapidly underestimated.

The explanation of the illusion by the general underestimation of rapid rates and overestimation of slow ones does not exclude the subordinate co-operation of other influences. It was found, for example, that with rapid rates the "after-image of movement" appeared clearly in the portion of the visual field corresponding to the slit. If this after-image could, to any degree, neutralize the perception of the actual movement, it might furnish a reason for the underestimation of the rapid rates.

A more certain factor is the distortion due to indirect vision.¹ Such a figure as the following will serve as an illustration:



On fixating the point the side of the circle next the fixation point will appear flattened, while the opposite side is more or less indistinct. With the figure passing alternately to and fro behind a slit, as in the hand apparatus, the flattening would occur on both sides, and the result would be a general impression of a laterally compressed ellipse. With the mechanical apparatus the flattening of the side next the fixation point may be obtained if merely a fine white thread, with a black knot for a fixation point, be hung before the travelling paper, the circle clearly seeming to change form as it passes from one side of the thread to the other. The flattening from this cause is too slight, however, to account for that observed in the original experiment, and the chief factor remains the false judgment of the rate of movement.

¹ Cf. Helmholtz, *op. cit.*, p. 697.